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THE RELATION OF IRRIGATION ON CANE FIELDS TO THE MALARIA PROBLEM.

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It is well known that in many parts of Porto Rico where malaria is particularly severe, irrigation of cane fields is practised and in any one region the highest rates of infection are usually found near or in these cane fields. Studies at Ponce based upon the examination of the spleens of 5000 children clearly demonstrated this fact. In the hills back of the city 9.5% of children were found with enlarged spleens - on the border of the city toward the cane fields, 17.4% were thus found, in the suburban zone, including the groups of houses just outside of the city, a rate of 29.2% was found, while in the colonies in the center of the irrigated fields the rate was 47%. At Fajardo the percentage of persons found infected was much higher in the cane fields than in the regions on the hills. Everywhere infection rates are much higher on the coastal plains than they are in the mountainous districts. Obviously the reason for these high rates must be found in or near the cane fields, but since most of these regions also have swamp areas and other water deposits at no great distances, the relative importance of irrigation in production of anopheles mosquitoes is difficult to determine. The fact that malaria is present where irrigation is not practised is proof that irrigation is not the only factor, but it is equally true that malaria is also present in higher regions in which irrigation channels are practically the only ones that contain water. Observations at Fajardo, Ponce and Aguirre clearly indicate that irrigation water in its course from the mountains through the cane fields to the ocean is, under certain conditions, a source of large numbers of malaria mosquitoes and is an important factor in any campaign to control the disease. In addition, the canals serve often for collection of rain water when irrigation is not practised and as the system may not serve equally well for drainage much breeding of anopheles mosquitoes take place.

The Main Supply Canals. - In regions where Government canals are present, water is usually drawn off from these; otherwise from rivers, deep wells, or seepage. Government canals are, as a rule, kept clean, water is constantly in motion and it is doubtful if many of these canals are sources of anopheles mosquitoes.

The problem in the main ditches during the usual season is twofold; (1) The margins become overgrown with grass and as they are not usually straight, excellent conditions are produced for anopheline breeding in indentations and vegetation even tho a swift current may flow thru the center. In cement lined canals the vegetation may extend over the sides of the canal until it reaches the water where it may give protection to larvae. During the driest months the effects of vegetation are somewhat offset by the changes in water level which are produced by the varying demand upon water for irrigation.

(2) Seepage and overflow from these ditches is also an important cause of anopheline breeding. This is commonly seen in regions where the canal passes along the side of a hill and the adjacent lowlands may be kept continuously wet. In other regions tubes which carry water over low places often leak or open canals overflow forming large wet areas below.

Reservoirs. - The smaller reservoirs would seem to serve mainly for collection of water during the night or other short periods when irrigation was not being practised. The larger ones serve to store water during periods of excess so that it may be used during periods of drought. During the seasons when the demands upon water are great the water level is changed often and the reservoir may become completely empty. No mosquitoes breed when either of these conditions exist.

During the periods of excess rain irrigation water is only occassionally needed and the water level in the reservoirs remains quite constant. In one instance near Ponce a small reservoir and a main supply channel almost 1 kilometer long leading to the reservoir were found filled with stagnant water for a period of almost two months during which time enormous numbers of anopheles larvae were found in the grassy margins. Reservoirs produce most mosquitoes when demands upon them are light and changes in water level slight. One between Ponce and Juana Díaz was practically dry during the dry season but for 3 months in the fall it was filled up to the point where it extended into adjacent cane fields and pasture lands, contained large amounts of debris and served as the breeding ground of enormous numbers of mosquitoes. Numerous other instances could be cited.

The Deep Wells. - As pointed out by Greene in work at Aguirre the sump pit at the sight of these wells commonly contains large amounts of water, especially in the rainy months. Numerous instances have been since, in which this water contained large numbers of larvae of malaria mosquitoes.

Distributing Ditches. - For lack of a better name the ditches which take water from the main supply ditches and deliver it to the individual fields are thus designated. These ditches are probably next to supply ditches the main sources of malaria mosquitoes and due to the fact that they are most abundant, probably are of more importance. The irrigator's view of the handling of water is that water is always moving and that it only stands in fields a comparatively short time, as

24-36 hours, and therefore cannot produce mosquitoes. Observations thus far have shown that water about the plants is handled as claimed, except in exceptional instances, for since the greatest production of cane is desired and stagnant water about plants reduces production, care of water in fields is as important as many of the procedures in the extraction of sugar. Lack of care means loss of money.

But water in the ditches which surround cane fields does not affect the growth of cane in the center of fields and lack of attention to stagnant water in these ditches does not affect the production of cane; but according to observations it increases the production of anopheles mosquitoes greatly and in the long run is loss to the Company due to the sickness among its labor.

METHOD OF HANDLING WATER.

Reference to a rough diagram of a system of irrigation may help to make the points clear. Water is drawn off of a main government canal or river "A" into main ditch "B" which may breed under conditions already stated.

(1) It is then desired to distribute the water to Field I. An opening is made in the side of canal B at point "1" so that water flows into distributing ditch C1 which is blocked at point "2" by a mud dam or "tapón" which raises the water to the necessary level to introduce water into the Field I. Dam "2" is often not made thick enough or high enough so that water overflows or seeps through into ditch C5 beyond and may fill it for a long distance.

(2) Field II is mature cane not needing irrigation but it is desired to carry the water beyond to Field III which is young cane. Water enters through opening "3" passes along ditch "C 2" to "C 6" at the end of which a dam (4) has been placed to raise the water to the necessary height. In order to keep water out of Field II a dam is placed at No. "4 A" several yards away from the distributing ditch "C" and an area of stagnant water between the ditch and dam "4 A" results. Since it is a field of mature cane there is always cane debris which affords protection for larvae. The dam could have been placed at the entrance to the ditch "D" and this stagnant water avoided. The position of the dam is of extreme importance from the standpoint of mosquito control for it is the rule to put it away from the entrance to the ditch. In a large area of cane fields the breeding area that is thus produced is quite considerable.

(3) It is thendesired to irrigate Field VI; both Fields IV and V being mature cane or cane not needing irrigation. Field VI is on relatively high ground and it is necessary to put a high dam at "6" to raise the water level sufficiently. The walls of ditch C 3 are often not made high enough or thick enough so that in raising the water level to reach Field VI water overflows into Fields IV and V, forming extensive breeding grounds.

Upon finishing the irrigation of Field VI a dam is often placed at 7 instead of at the entrances of the ditch at main canal "B". A long line of stagnant water is thus formed in "C 3" and since it is in a field with high cane there is always grass along the margins of the ditch and debris of cane leaves, which furnish excellent conditions for breeding. When it is necessary to raise the water to get it into high lands the walls of ditches generally flare out considerably as they are made higher, and as the final distributing ditch is small very little current is found in the main canal.

(4) In case of irrigation of Field VII which is the last one supplied by ditch "B" which from then on may be a drainage ditch, the dam is placed at "8" instead of at the entrance to ditch "C 4" and a ditch of stagnant water is thus formed. In case that all fields in this area have been irrigated, all entrances to fields are closed and the dam at "8" may be left in. There is then more or less direct communication with A so that B is entirely filled with water between irrigation. A long ditch with stagnant water is thus produced. This is often done purposely in very dry seasons to help keep the land moist by filtering of water from the ditch. Numerous dams may be left in place along its course to hold the water for this purpose. In soils which do not absorb rapidly water may stand in some of these ditches from one irrigation to the next.

(5) The ground water level is undoubtedly raised in the lower lands by seepage from irrigation on the higher lands so that often extensive wet areas are produced which form breeding grounds for anopheles mosquitoes.

(6) In many cases drainage channels lead directly to a river or the ocean so that disposal of water is promptly taken care of. Often, however, the grade is low, vegetation covers the banks of the ditches, which may become partially blocked by debris and dirt. Since there is either rain or irrigation at all times, these drainage ditches have water more or less continuously.

At other times the water is poured into pasture land either because there is no other convenient place to put it or in order to obtain as good a growth of grass as possible. In either case the practice cannot be condemned too thoroughly from the standpoint of danger as source of malaria mosquitoes when the pastures are near residences.

Effect of Rain. - The dams have been shown to be important factors in producing conditions favorable for breeding of mosquitoes during the dry months. Since irrigation ditches also serve as drainage ditches during the rainy months and since all dams are not removed or only partially so, drainage is seriously impeded and series of stagnant pools above the dams are found. It is during these months that anopheles mosquitoes are more active. Canals that previously were being constantly used and

oftentimes almost dried because of excessive demands of irrigation are now not used at all, become filled with more or less stagnant rain water, or serve as drainage ditches which are not well cared for. The water they contain is outside of the cane fields, does not affect the growth of cane but serves as excellent breeding areas for mosquitoes.

The problem of control of malaria in swamp lands by antimosquito measures is a problem in itself. For control of breeding in irrigated cane fields, however, there are a few principles which, if applied, ought to reduce remarkedly the production of mosquitoes. Changing the level of water at short intervals of 4-5 days or a week, permitting irrigation ditches to run as nearly dry as possible and then filling again will produce remarkable results in reservoirs and ditches which do not contain floating debris or vegetation. Attention to proper placing and construction of dams as well as their complete removal when not needed is also quite essential. The good obtained by permitting dams to remain in place in order to collect water which may seep into adjacent fields must be enormous to offset the damage done by mosquitoes breeding in this stagnant water. From the standpoint of malaria control the practice is extremely dangerous. Reasonable care of drainage channels to provide adequate and prompt discharge to river or ocean will be of great aid in the campaign. For the further studies of these and many other points a campaign is in progress at Fajardo for the control of malaria and it is expected that the desired results will be obtained, in a reasonable length of time.

SKETCH OF IRRIGATION SYSTEM.